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# A Composite Medium Approximation for Moisture Tension-Dependent Anisotropy in Unsaturated Layered Sediments

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Sedimentary formations often have a layered structure in which hydrogeologic properties have substantially larger correlation length in the bedding plane than perpendicular to it. Laboratory and field experiments and observations have shown that even small-scale layering, down to millimeter-size laminations, can substantially alter and impede the downward migration of infiltrating liquids, while enhancing lateral flow. The fundamental mechanism is that of a capillary barrier: at increasingly negative moisture tension (capillary suction pressure), coarse-grained layers with large pores desaturate more quickly than finer-grained media. This strongly reduces the hydraulic conductivity of the coarser (higher saturated hydraulic conductivity) layers, which then act as barriers to downward flow, forcing water to accumulate and spread near the bottom of the overlying finer-grained material.

We present a "composite medium approximation" (COMA) for anisotropic flow behavior on a typical grid block scale (0.1 - 1 m or larger) in finite-difference models. On this scale the medium is conceptualized as consisting of homogeneous horizontal layers with uniform thickness, and capillary equilibrium is assumed to prevail locally. Directionally-dependent relative permeabilities are obtained by considering horizontal flow to proceed via "conductors in parallel," while vertical flow involves "resistors in series." The model is formulated for the general case of N layers, and implementation of a simplified two-layer (fine-coarse) approximation in the multiphase flow simulator TOUGH2 is described. The accuracy of COMA is evaluated by comparing numerical simulations of plume migration in 1-D and 2-D unsaturated flow with results of fine-grid simulations in which all layers are discretized explicitly. Applications to water seepage and solute transport at the Hanford site are also described. This work was supported by the U.S. Department of Energy under Contract No. DE-AC03-76SF00098 through Memorandum Purchase Order 248861-A-B2 between Pacific Northwest National Laboratory and Lawrence Berkeley National Laboratory.